Knight: Chapter 16

A Macroscopic Description of Matter

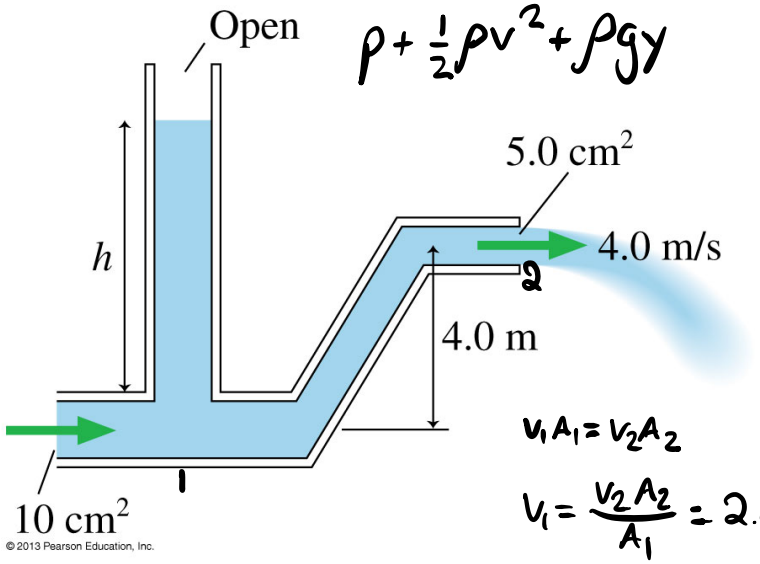
(Solids, Liquids, and Gases, Atoms and Moles, & Temperature)

Prob. 15.60

Water flows from the pipe shown in the figure below with a speed of 4.0 m/s.

a. What is the water pressure as it exits into the air?

b. What is the height h of the standing column of water?



$$p + \frac{1}{2}\rho v^2 + \rho g y$$

$P_2 = P_{atm}$

$P_1 = p_{atm} + \rho g h$

$A_1 = 10\ cm^2$

$A_2 = 5.0\ cm^2$

$V_2 = 4.0\ m/s$

$V_1 = 2.0\ m/s$

$V_1 A_1 = V_2 A_2$

$$V_1 = \frac{V_2 A_2}{A_1} = 2.0 m/s$$

$$P_1 + \frac{1}{2}\rho V_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho V_2^2 + \rho g y_2$$

$$\cancel{P_{atm}} + \rho g h + \frac{1}{2}\rho V_1^2 + \rho g y_1 = \cancel{P_{atm}} + \frac{1}{2}\rho V_2^2 + \rho g y_2$$

$$\rho g h = \frac{1}{2}\rho(V_2^2 - V_1^2) + \rho g(y_2 - y_1)$$

$$h = \frac{(V_2^2 - V_1^2)}{2g} + (y_2 - y_1)$$

$$h = \frac{(12.0 m^2/s^2)}{19.6 m/s^2} + (4.0 m)$$

$h = 4.6 m$

$h = 4.6\ m$

Quiz Question 1

An ideal fluid is pumped steadily up a vertical pipe with a uniform cross-section. The difference in pressure between a point at the top and at the bottom

1. is the same as it would be if the fluid were motionless.
2. is greater at higher flow rates than at lower flow rates.
3. is less at higher flow rates than at lower flow rates.
4. does not depend on the density of the fluid.
5. is zero.

$A_1 = A_2 \qquad v_1 = v_2$

$$p_1 + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 = p_2 + \tfrac{1}{2}\rho v_2^2 + \rho g y_2$$

$$p_1 = p_2 + \rho g(y_2 - y_1)$$

$$p_1 = p_2 + \rho g h$$

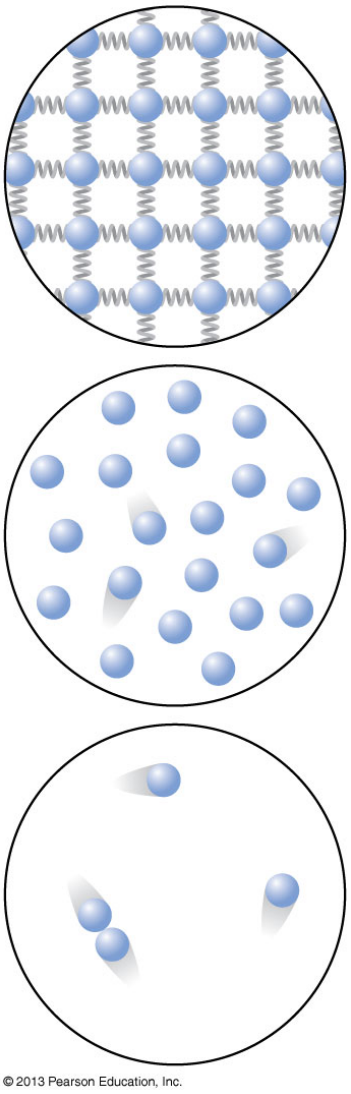
Solids, Liquids, & Gases

Solids..

- *rigid* macroscopic system consisting of particle-like atoms connected by spring-like molecular bonds.
  - each atom vibrates around an equilibrium position but otherwise has a fixed position.

Liquids..

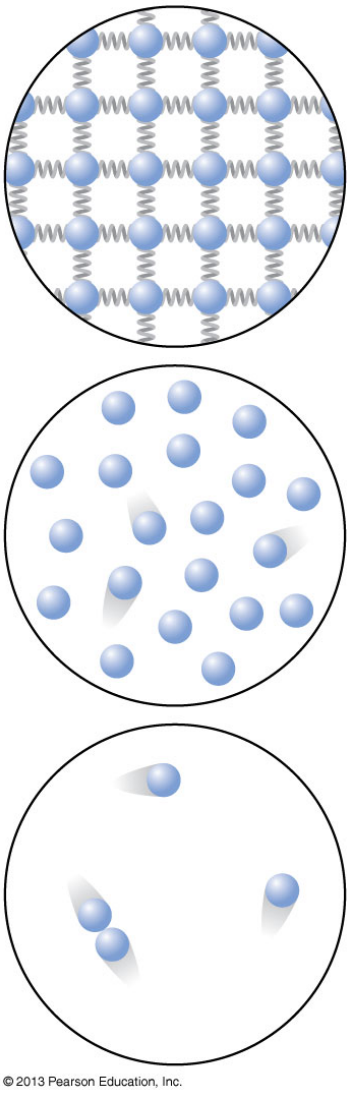
- nearly *incompressible* (the molecules are about as close together as they can get).
- *flow and deform* to fit the shape of its container (molecules are free to move around).



Solids, Liquids, & Gases

Gases..

- a system in which each molecule moves through space as a *free, noninteracting particle* until it collides
  - with another molecule
  - with the wall of the container.
- are *fluids*, and highly *compressible*.



Volume and density

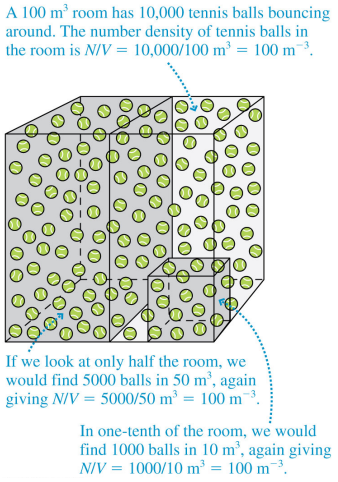
Mass density…

$$\rho \equiv \frac{M}{V}$$ with SI units: $$[\rho] = \frac{\text{kg}}{\text{m}^3}$$

M for the *system mass* & *m* for the *mass of an atom*.

Number density…

$$\frac{N}{V}$$ with SI units: $$\frac{1}{\text{m}^3}$$



Atomic Mass & Atomic Mass Number

- Mass of an atom is determined primarily by: protons and neutrons.
- *Atomic mass number*:

$$A = \text{proton } \# + \text{neutron } \#$$

- *Atomic mass:*
- $\simeq$ atomic mass number.
- u is the *unit of atomic mass.*

$$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$$

Element		*A*
^{1}H	Hydrogen	1
^{4}He	Helium	4
^{12}C	Carbon	12
^{14}N	Nitrogen	14
^{16}O	Oxygen	16
^{20}Ne	Neon	20
^{27}Al	Aluminum	27
^{40}Ar	Argon	40
^{207}Pb	Lead	207

Moles and Molar Mass

Q: What is a mole, *n*?

- The # of molecules contained in 1 mole of *any* gas is Avogadro's number, N_A, so

$$n = \frac{N}{N_A}$$

where

- n is the # of moles
- N is the # of atoms or molecules in a gas
- $N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$

$N_A \approx 6.02 \times 10^{23}\ \text{mol}^{-1}$

More on moles…

The # of moles in a system of mass M consisting of atoms or molecules with molar mass M_{mol} is

$$n = \frac{M}{M_{mol}}$$

- with SI units:

$$[M_{mol}] = \text{kg/mol}$$

- Q: What is the molar mass of Carbon 12?
- A: 0.012 kg/mol
- Q: What is the molar mass of O_2?
- A: 0.032 kg/mol

Moles and Molar Mass

If atomic mass m is in kg, the # of atoms in a system of mass M can be found from:

$$N = \frac{M}{m}$$

Quiz Question 2

Which contains more molecules, a mole of hydrogen gas, H_2, or a mole of oxygen gas, O_2?

1. H_2.
2. O_2.
3. They each contain the same # of molecules.
4. Can't tell without knowing their temperatures.

i.e. 16.2: Moles of Oxygen

100 g of oxygen gas is how many moles of oxygen?

$n = \frac{N}{N_a}$ $\quad M = 0.1\,kg$

$n = \frac{M}{m}$ $\quad m = 0.032\,kg/mol$

$N = \frac{M}{m}$ $\quad N = \frac{0.100\,kg}{0.032\,kg/mol} = 3.125\,mol$

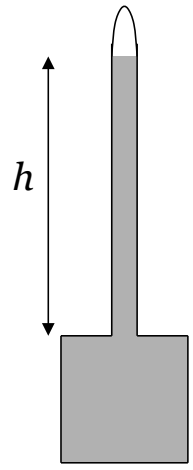
$m = 32 \times 1.66 \times 10^{-27}\,kg = 5.312 \times 10^{-26}\,kg$

$M = 0.100\,kg$

$N = \frac{0.100\,kg}{5.312 \times 10^{-26}\,kg} = 1.88 \times 10^{24}$

$n = \frac{N}{N_a} = \frac{1.88 \times 10^{24}\,N}{6.02 \times 10^{23}\,N/mol} = 3.127\,mol$

Thermometers & Temperature Scales



Thermometers

- are used to measure the temperature of an object or a system.
- The level of the mercury rises due to *thermal expansion*.
- 3 different scales
  - Celsius
  - Kelvin
  - Fahrenheit

Temperature Unit Conversions

$T_K = T_C + 273.15$

$T_F = \frac{9}{5} T_C + 32$

$\frac{5}{9}(T_F - 32) = T_C$

Kelvin Temperature Scale

- *Absolute Zero : T = 0K = -273.15°C (Pressure of a gas -> zero)*

Celsius Temperature Scale

- *T = 0°C - Freezing point of H_2O, T = 100°C - Boiling point of H_2O*

Fahrenheit Temperature Scale

- *T = 32°F - Freezing point of H_2O, T = 212°F - Boiling point of H_2O*

Quiz Question 3

Which is the largest increase of temperature?

1. An increase of 1°F.
2. An increase of 1°C.
3. An increase of 1 K.
4. Both 2 and 3, which are the same and larger than 1.
5. 1, 2, and 3 are all the same increase.